

# Development of Steel Pipe Business and Manufacturing Technology of JFE Steel

SATO Hideo

## Abstract:

*JFE Steel has facilities for manufacturing seamless steel pipes and various welded steel pipes, which support wide range of requests from customers. Products with distinctive characteristics are as follows, such as stainless steel OCTG, large diameter HFW pipe with excellent low temperature toughness, Mighty Seam<sup>TM</sup>, UOE pipe for high strength and high performance linepipes, and a high performance and high workability welded steel pipe for automotive parts. This paper outlines the features of the manufacturing process, improvements of the manufacturing technology and typical pipe and tube products in JFE Steel.*

## 1. Introduction

JFE Steel manufactures steel pipes at three plants, East Japan Works (Keihin), West Japan Works (Fukuyama) and Chita Works, which specializes in steel pipe manufacturing. By production method, the company has lines for manufacturing seamless pipes and various types of welded steel pipes, including butt welded pipes, high frequency welding (HFW) pipes and UOE pipes, and has constructed a system that supplies steel pipe products supporting a wide range of customer needs.

## 2. Features of JFE Steel's Steel Pipes

### 2.1 Pipe Manufacturing System

**Figure 1** shows an outline of the steel pipe manufacturing process in JFE Steel. Seamless pipes are manufactured by the Mannesmann mandrel mill process and the Mannesmann plug mill process. Welded pipes can be divided into three types of manufacturing processes by the welding method, i.e., the arc welding method, the high frequency electric resistance welding (HFW) method and the butt welding method. Pipes produced by the arc welding method can be further divided into

UOE steel pipes and press bend steel pipes, according to the forming method. Among welded pipes, hot-rolled steel sheets are used as the material for butt welded steel pipes and HFW steel pipes produced by electric resistance welding, and steel plates are used as the material for UOE pipes and press bend pipes.

As production facilities for seamless steel pipes, JFE Steel has two lines at Chita Works, and for UOE pipes, the company has one line at West Japan Works (Fukuyama). For ERW pipes, JFE operates one line at East Japan Works (Keihin) and three lines at Chita Works, and for butt welded pipes, it has one line at East Japan Works (Keihin). **Table 1** shows the manufacturing facilities for steel pipes and tubes in JFE Steel, together with the available size ranges of the products.

The available size ranges (outside diameter, wall thickness) of each type of steel pipe product are shown schematically in **Fig. 2**. The available size range differs depending on the type of material and the processing and forming methods. Products suited to the applications and needs of the customer can be manufactured by the most appropriate method.

The features of the steel pipe manufacturing technologies of JFE Steel are introduced in the following.

### 2.2 Seamless Pipe Manufacturing Facilities

JFE Steel has two manufacturing lines for seamless steel pipes, the small-diameter seamless pipe mill using the Mannesmann mandrel process and the medium-diameter seamless pipe mill using the Mannesmann plug mill process, both located at Chita Works. The small-diameter seamless pipe mill produces steel pipes with outside diameters from 25.4 mm (1 inch) to 177.8 mm (7 inches), while the medium-diameter seamless pipe mill produces products with outside diameters from 177.8 mm (7 inches) to 426.0 mm (16-3/4 inches).

Among the materials used to manufacture seamless steel pipes, carbon steel and low alloy steel are melted and rolled at West Japan Works (Kurashiki) and supplied to Chita Works. High alloy steel materials, repre-

<sup>†</sup> Originally published in *JFE GIHO* No. 54 (Aug. 2024), p. 1–7

General Manager, Planning & Marketing Dept., Tubular Business Division, JFE Steel (currently, President, JFE Connections America)

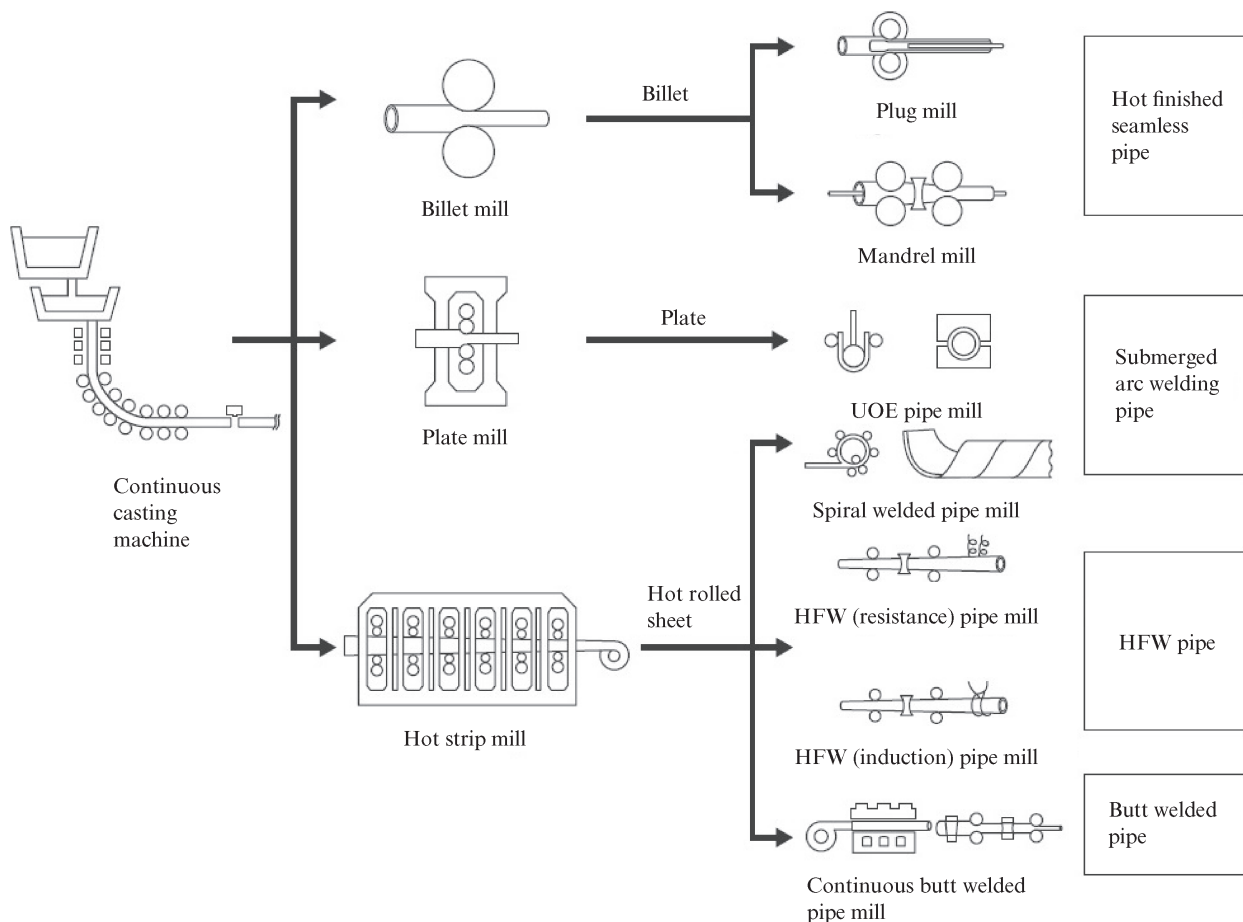


Fig. 1 Manufacturing processes of pipes and tubes in JFE Steel

sented by 13% Cr steel, are melted and cast into slabs at East Japan Works (Chiba), and the cast slabs are bloomed at West Japan Works (Kurashiki) and supplied to Chita Works in the form of billets.

JFE Steel has devoted great effort to high Cr seamless pipes, which are used primarily in oil country tubular goods (OCTGs) and boiler tubes, and possesses a high level of know-how related to manufacturing technologies for these product groups. In the past, high Cr alloy steels and stainless steel seamless pipes were generally rolled after piercing by the hot extrusion process. JFE Steel was the first in the world to succeed in mass-producing products with stable quality by manufacturing these products by the Mannesmann piercing process. This was realized by improvement of the properties of the material by heavy reduction processing in the stage after continuous casting, together with establishment of the manufacturing technology, including optimization of the technology for billet temperature control and piercing conditions, optimization of the rolling schedule on mandrel mill, etc. during pipe rolling<sup>1)</sup>.

JFE Steel also has heat treatment equipment for producing the required product properties, and finish-

ing lines and inspection lines that make it possible to perform various types of nondestructive testing (NDT) conforming to the needs of the customer.

Since threaded joints are applied to connect the individual tubes when OCTGs are used, JFE Steel also has processing facilities for manufacturing threaded joints.

### 2.3 UOE Pipe Manufacturing Equipment

JFE Steel has one UOE mill, which is located at West Japan Works (Fukuyama) and is mainly used to manufacture high grade linepipes.

In order to manufacture high quality linepipes, the properties and quality of the steel plates used as the material are important. The material such as steel plate for UOE pipes manufactured by JFE Steel is supplied by West Japan Work (Fukuyama). The plate mill at Fukuyama is equipped with the state-of-the-art thermo-mechanical heat treatment equipment, *Super-OLAC*<sup>TM</sup>-A, and the world's only on-line heat treatment equipment, HOP<sup>2)</sup>. The plate mill also has a high efficiency press bend press, NEO Press<sup>TM</sup>, to support production of high strength, heavy wall pipes.

Table 1 Manufacturing facilities for pipe and tube production in JFE Steel

Manufacturing method	Location	Manufacturing facilities	Available size (mm)			Remarks
			Outside diameter	Wall thickness	Max. length	
Hot finished Seamless	Chita Works	Small-diameter seamless steel pipe mill	25.4-177.8	2.3-40.0	28 500	Mandrel mill rolling
	Chita Works	Medium-diameter seamless steel pipe mill	177.8-426.0	5.1-65.0	13 500	Plug mill rolling
SAW	West Japan Works (Fukuyama)	UOE steel pipe mill	406.4-1 422.4	6.0-50.8	18 300	Outside coating, Inside coating
	East Japan Works (Chiba)	Spiral steel pipe mill	500.0-2 600.0	6.0-30.0	25 000	JFE Welded Pipe
HFW	Chita Works	6-inch HFW steel pipe mill	60.5-165.2	2.0-12.7	16 000	JFE Welded Pipe
	Chita Works	4-inch HISTORY™ steel pipe mill	21.7-76.3	2.0-10.0	7 500	JFE Welded Pipe
	Chita Works	26-inch HFW steel pipe mill	318.5-660.4	4.0-25.4	20 000	
			250.0-550.0	6.0-28.0	14 000	Square columns
	East Japan Works (Keihin)	24-inch HFW steel pipe mill	177.8-609.6	3.2-19.1	18 500	Max. 12 000 mm for outside coating
			200.0-500.0	4.5-22.0	18 000	Square columns
Butt welding	East Japan Works (Keihin)	Butt welded steel pipe mill	21.7-114.3	2.8-4.5	7 200	Max. 7 200 mm for outside coating

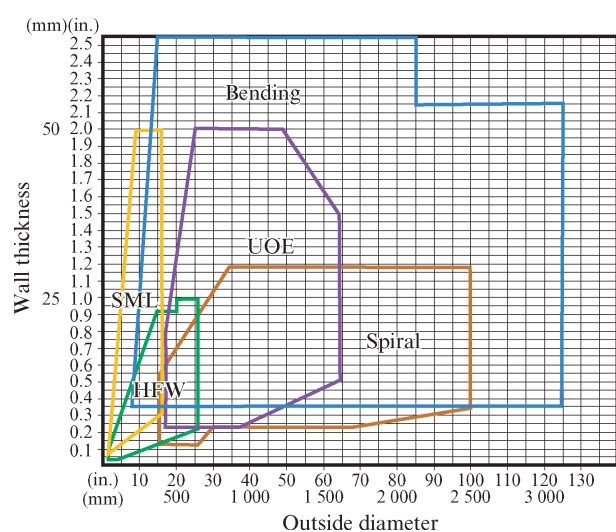


Fig. 2 Product size range

## 2.4 HFW Pipe Manufacturing Equipment

As manufacturing equipment for HFW welded pipes, JFE Steel has three production lines at Chita Works and one line at East Japan Work (Keihin).

These manufacturing lines have their own respective features, and JFE has established a system that produces the optimum product corresponding to the applications of steel pipes. It may be noted that operation of the small-diameter HFW pipe line and the HISTORY™

pipe line at Chita Works has been outsourced to JFE Welded Pipe Manufacturing Co., Ltd. (JFE-WP).

### 2.4.1 Medium- and large-diameter HFW pipes

Medium- and large-diameter HFW pipes are manufactured by two lines, the 26" HFW pipe mill at Chita Works and the 24" HFW pipe mill at East Japan Works (Keihin). Both mills can manufacture round steel pipes and square steel pipes.

The 26" HFW pipe mill at Chita Works is capable of forming pipes with the world's largest class outside diameter and pipe wall thickness, and has commercialized extra-heavy wall HFW linepipes and conductor casings as substitutes for large-diameter, heavy wall UOE pipes which are a strong point of the Chita mill by utilizing these features.

One strength of the 24" HFW pipe mill at East Japan Works (Keihin) is its lineup of comparatively small-diameter products. In particular, this mill produces a lineup with outstanding weld seam quality under the tradename Mighty Seam™. Mighty Seam combines JFE Steel's proprietary HFW welding technology and quality assurance technologies, and is a product lineup with excellent low-temperature toughness.

Mighty Seam can be produced at both East Japan Works (Keihin) and Chita Works.

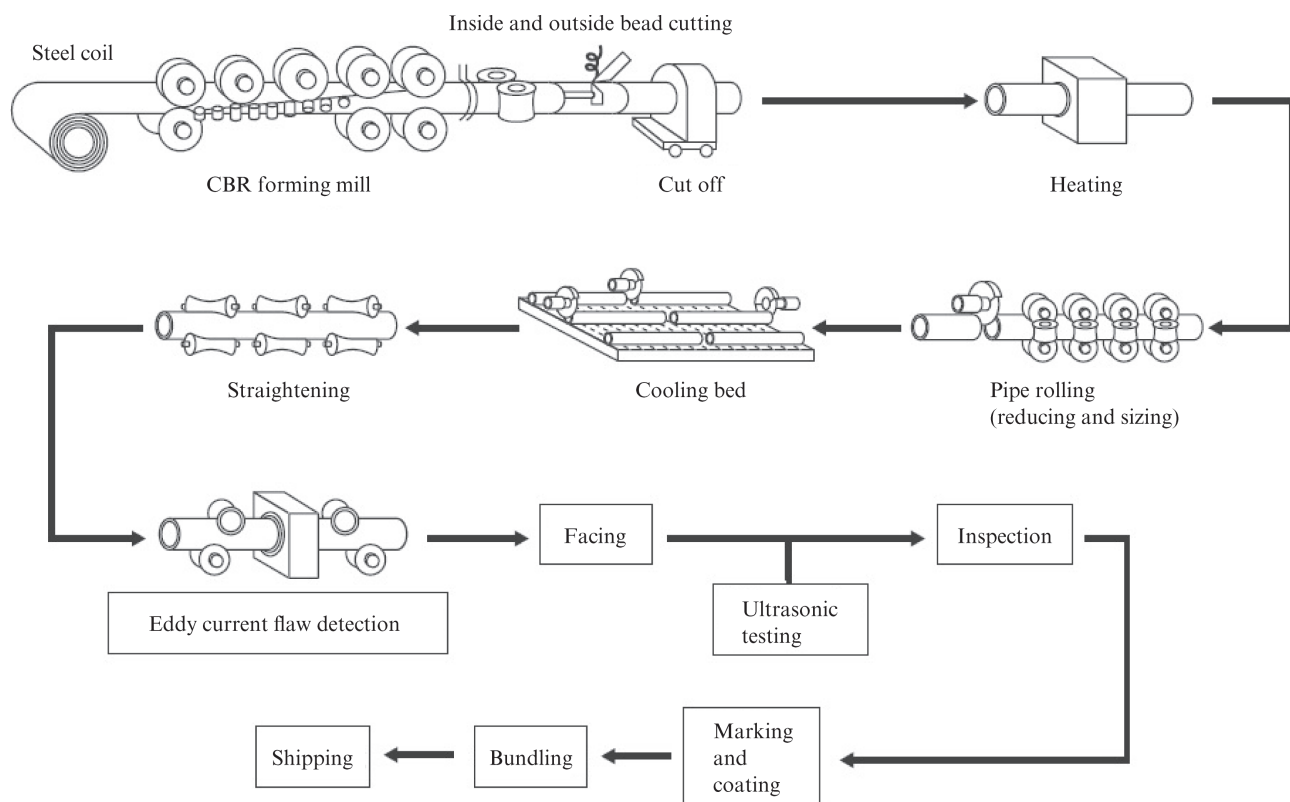


Fig. 3 Schematic manufacturing procedure of HISTORY™ pipe

#### 2.4.2 HISTORY™ steel tube

The 4" HISTORY pipe mill at Chita Works is a JFE original manufacturing process. Products with a combination of high strength and high formability are produced by forming the steel strip by the Chance free Bulge Roll (CBR) forming process, welding by high frequency electric resistance welding (HFW), induction heating after cutting off the internal and external welding beads, and diameter reduction.

As materials for machine structures that satisfy both high strength and high formability requirements, HISTORY steel tubes were developed for applications which assume high workability, such as automobile suspension parts<sup>3)</sup>. The HISTORY tube manufacturing process is shown in Fig. 3. After conventional HFW welding, the tubes are heated and subjected to warm diameter reduction rolling. Strength and ductility are improved by realizing crystal texture deformation simultaneously with refinement of the crystal grain size and refinement of carbides. When used as automotive parts, HISTORY products can contribute to a weight reduction of 20 to 30%. It is also possible to produce small-diameter, thick-walled pipes that had been difficult to manufacture as conventional HFW welded pipes, and hardening of the weld can also be eliminated by forming the tubes while warm.

#### 2.4.3 Outside coating

The 24" pipe mill at East Japan Works (Keihin) has outside coating equipment and can manufacture pipes in which an outside coating is required.

#### 2.5 Butt welded pipe mill

The butt welded pipe mill at East Japan Works (Keihin) mainly produces the SGP products (Steel Pipe for ordinary Piping) specified in the Japanese Industrial Standards (JIS). The mill manufactures galvanized steel pipes and resin-coated corrosion-proof pipes used in piping for liquefied nature gas (LNG) and water supply. It also produces the lightweight steel pipes FAST™ 10 and FAST™ 20 with lighter weights than the conventional SPG to reduce CO<sub>2</sub> in the pipe manufacturing process and improve workability.

### 3. Steel Pipe Products

JFE Steel supplies various steel pipe products for a wide range of applications. For the energy industry, these include OCTG, <sup>4,5)</sup>, which are used in oil and natural gas drilling and production, linepipes used in transportation of these resources, and boiler tubes used in electric power generation. JFE pipe products such as steel tube columns and steel tube piles are widely used in construction, and material tubes for automotive

Table 2 Available grades of OCTG (Oil Country Tubular Goods)

Yield strength (ksi)	API seamless	API enhanced				Sour service	For CO <sub>2</sub> service (JFE's proprietary grades)			
		1%Cr	Controlled yield	High collapse	Mild sour		Pure sweet	Sweet high temp.	Sweet high temp. (+Slight sour)	Severe sweet high temp. (+Slight sour)
80	N80 L80 L80-13CR	L80-1Cr				JFE-80S	JFE-13CR-80			
85							JFE-13CR-85			
90	C90					JFE-90S				
95	R95 T95		T95-E	T95-HC/HCX		JFE-95S	JFE-13CR-95	JFE-HP1-13CR-95	JFE-HP2-13CR-95,95M (ISO13680)	
110 /115	P110 C110	P110-1Cr	P110-RY P110-E	P110-HC/HCX C110-HC/HCX	P110-MS	C110-XS		JFE-HP1-13CR-110	JFE-HP2-13CR-110,110M,115 (ISO13680)	JFE-UHP <sup>TM</sup> -17CR-110
125	Q125		Q125-RY	Q125-HC/HCX		JFE-125S				JFE-UHP <sup>TM</sup> -15CR-125

parts are used in diverse applications in the automotive industry. The following introduces representative products.

### 3.1 OCTG

JFE Steel manufactures and sells distinctive products for applications that require corrosion resistance, as shown in **Table 2**. One of these products is high strength and high corrosion resistance OCTG that can be used in environments where CO<sub>2</sub> exists, and another is OCTG for sour service in environments containing H<sub>2</sub>S. JFE also sells premium joints which are suitable for these high strength OCTG. In addition to the grades provided in the API standard, as high performance OCTG for tubing/casing use, JFE manufactures high collapse OCTG, which is capable of withstanding collapse, and OCTG for low-temperature service, which can be used in low-temperature environments.

#### 3.1.1 High strength and high corrosion resistance OCTG<sup>4,5)</sup>

The distinctive OCTG produced by JFE Steel include a series of high strength and high corrosion resistance OCTG that utilize the properties of martensitic stainless steel. In addition to conventional 13% Cr steel, JFE supplies a diverse lineup of products for various use environments, including JFE-HP1-13CR and JFE-HP2-13CR with improved strength and corrosion resistance by addition of alloying elements, and JFE-UHP<sup>TM</sup>-15CR and JFE-UHP<sup>TM</sup>-17CR, which can be applied in environments where duplex stainless steel had been used conventionally.

#### 3.1.2 Premium joints

High joint strength and excellent sealability are required in the threaded joints that connect OCTG tubes used in high-depth oil/gas wells. As proprietary premium joints (PJ), JFE Steel supplies five types, FOX<sup>TM</sup>, JFEBEAR<sup>TM</sup>, JFETIGER<sup>TM</sup>, JFELION<sup>TM</sup> and JFECOBRA<sup>TM</sup>, and also supplies JFERABBIT<sup>TM</sup> as a semi-premium joint<sup>6)</sup>. To reduce the risk of spills into the environment of environmentally-harmful substances contained in the lubricants used when making up connections in the field, the joint lubrication system CLEAR RUN<sup>TM</sup> is used<sup>6)</sup>.

### 3.2 Linepipe

JFE Steel has manufacturing processes for seamless pipes, UOE pipes<sup>7)</sup> and HFW welded pipes<sup>8,9)</sup>, and supplies appropriate materials corresponding to the application and size range.

JFE has lines of products with distinctive features that include high-strength linepipe for use in pipelines, which are the longest/largest among these applications, Mighty Seam<sup>10)</sup> with highly-reliable weld quality in comparison with conventional welded pipes, and martensitic stainless steel linepipes<sup>11)</sup> that can be used in corrosive environments, among others.

#### 3.2.1 High-strength linepipe

Even in high-strength linepipes, represented by X80, use of products with heavier wall thicknesses is progressing accompanying high-pressure transportation in pipelines and demand for larger diameter pipes. To



meet stricter low temperature toughness requirements, JFE Steel developed a new welding process that can further improve weld toughness, and established a high efficiency, high quality manufacturing system.

### 3.2.2 Linepipe for sour service

When H<sub>2</sub>S is present, there is a possibility of hydrogen induced stress cracking (HIC), even in pipelines in the same oil well environment. Linepipe for sour service is used to prevent HIC, as the amount and shape of impurities, and particularly S, is suppressed. JFE Steel can supply linepipes for sour service with strength up to X65, and can also respond to strict surface layer hardness requirements. The response to strict surface layer hardness requirements is introduced in this issue.

### 3.2.3 Mighty Seam<sup>TM</sup>

The environments where oil and natural gas are produced and transported are becoming increasingly severe. JFE Steel put great effort into the development of welding technologies for welded steel pipes for linepipes and nondestructive testing technologies for the seam weld, leading to the development of the new HFW pipe Mighty Seam with dramatically improved seam weld reliability. As a result, it is now possible to design linepipes that utilize the characteristic high dimensional accuracy, high toughness and other features of welded pipes.

### 3.2.4 Martensitic stainless steel linepipe

Until now, duplex stainless steel, etc. had been used as corrosion-resistant materials for linepipes. However, while duplex stainless steel has excellent corrosion resistance, it had been pointed out that the material cost is extremely high, welding heat input control is difficult, and cracking tends to occur if corrosion protection is excessive.

Martensitic stainless steel<sup>11,12)</sup> shows good CO<sub>2</sub> corrosion resistance, and compared with duplex stainless steel, it is a low cost material. JFE Steel improved the weldability of this material by reducing the contents of C and N, and after further adjustment of the added components, produces martensitic stainless steel HFW pipes for linepipes with excellent weldability and corrosion resistance.

## 3.3 Specialty Pipes and Tubes

Utilizing its manufacturing technologies for high Cr alloys, JFE Steel manufactures improved 9% Cr-1% Mo steel pipes (T91/P91) and W-added 9% Cr steel pipes (T92/P92), which are used in boilers for thermal power generation and in petrochemical plants. It is possible to manufacture pipes with a maximum length of 28.5 m.

In addition to high Cr alloys, JFE Steel also manufactures and sells other products with distinctive features such as heavy-wall steel pipes for hydrogen accumulators, etc.

## 3.4 Structural Pipes

Materials that utilize the characteristic features of steel pipes are widely used in the civil engineering and construction fields.

In addition to the steel pipe piles that support the foundations of civil engineering and building structures, JFE Steel has also developed the rotary penetration steel pipe pile with toe wing, TSUBUSA (Wing) PILE with improved workability, and the inner pile excavation method using steel pipe pile (KING method).

Square column steel pipes are finished to a square shape by rolls in the pipe manufacturing process. JFE Steel boasts a rich lineup, which includes JFE Column, in which HFW welded steel pipes are used as the material, and Kakuhot<sup>TM</sup> using seamless pipes as the material. In the JFE Column line, JFE produces JBCR<sup>TM</sup>295 with a maximum thickness of 28 mm and the high-strength grade JBCR<sup>TM</sup>385. Kakuhot is an original JFE product and is adopted in buildings in which a design property is required.

## 3.5 Automotive Steel Tubes<sup>13)</sup>

Examples of the adoption of steel tubes in automotive suspension parts for automobile weight reduction are increasing. In addition to materials and product development, JFE Steel is carrying out work to link secondary processing technologies for steel tubes and performance evaluation techniques. JFE's HISTORY steel tube has been adopted as a material for automotive suspension parts, centering on stabilizers.

## 3.6 Steel Pipes for Piping Applications

Use of resin pipes and stainless steel pipes as piping materials for gas, water supply, etc. is increasing, but the use ratio of steel pipes, represented by galvanized steel pipes and corrosion-resistant steel pipes, continues to be high. In recent years, there has been heightened demand for weight reduction of steel pipes to improve workability at construction sites, and in response, JFE Steel developed the lightweight steel pipes FAST10 and FAST20, which reduce weight by 20% in comparison with the conventional pipes.

In addition, corrosion-resistant coated pipes, in which a resin coating is applied to the inside surface or outside surface, are also widely used in gas pipes, water supply pipes, etc. **Table 3** shows the major coated pipes produced by JFE Steel and their features.

Table 3 Major products of coated pipes

Product	Feature
Carbon Steel Pipe for Plumbing	This steel pipe, which is galvanized both inside and outside, offers outstanding workability.
Galvanized Steel Pipe for Water Plumbing (SGPW)	This steel pipe, which is thickly galvanized both inside and outside, offers outstanding workability.
Mizonon MZN (Grooving Corrosion resistant Electric-Resistance Welded Carbon Steel Pipe)	When electric resistance welded pipe is used for seawater, industrial water or water works application, the seam portion may be selectively corroded, and so-called groove corrosion occurs. "Mizonon" is an electric resistance welded carbon steel pipe that is designed to prevent groove corrosion.
PFP (Internal Polyethylene Fusion Bonded Steel Pipe for Water Supplies)	This corrosion-resistant steel pipe for water supplies is coated on the inside with powdered polyethylene. It boasts excellent quality, hygiene, and corrosion-resistance. The fitting combined with rolling thread with excellent seismic resistance and durability. Conformable to JWWA K132.
JLP (Internal Unplasticized PVC-Lined Steel Pipe for Water Supplies)	This corrosion-resistant steel pipe for water supplies is made by lining the inside of steel pipe with PVC pipe using a bonding agent. It is ideal for applications that require a high level of corrosion protection. Conformable to JWWA K116.
JDLP (Internal PVC-Lined Steel Pipe for Building Drainage Services)	This is lightweight steel pipe lined with unplasticized PVC to address the need for more flexible and higher structures as a result of the diversification of drainage services and the increasing height of high-rise buildings. These products are conformable to WSP-042 (PVC-Lined Steel Pipe for Drainage).
PLP-PE2S (External Polyethylene-Coated Steel Pipe)	The outside of this corrosion-resistant steel pipe for underground plumbing is seamlessly coated with polyethylene resin by extrusion, to achieve a high degree of corrosion-resistance. Conformable to JIS G 3477-2 PE2S.
PLP-PE1H (External Single-Layer Bonded Polyethylene-Coated Steel Pipe)	This single-layer bonded polyethylene-coated steel pipe is made by strongly bonding a polyethylene coating onto steel pipe. It is suitable for laying underground and is conformable to JIS G3477-2 PE1H.
PLS (External Small-Diameter Single-Layer Bonded Polyethylene-Coated Steel Pipe)	This small-diameter single-layer bonded polyethylene-coated steel pipe retains the corrosion-resistance of PLP and can be used with its coating for thread cutting and thread rolling. Conformable to JIS G3477-2 PE1H.
PLS-F (Small-Diameter Single-Layer Bonded Polyethylene-Coated Steel Pipe)	Adhesive type polyethylene-coated steel pipe with ivory resin to match the color of building. Conformable to JIS G3477-2 PE1H.
PLV (External Unplasticized PVC-Coated Steel Pipe)	This is an integrally molded product made by strongly bonding PVC to steel pipe. It can be used for cutting and thread cutting without the coating peeling off and is also suitable for thread rolling. The use of highly weather-resistant PVC enable use for both underground and exposed plumbing.
Fire-Fighting Pipe VS, VS-M (Galvanized and External unplasticized PVC-Coated Steel Pipe for Fire-Fighting)	It is adopted in the common equipment specification of the machine equipment work of Ministry of land, infrastructure, transport and Tourism. Fire-Fighting Pipe VS conforms to WSP-041 (Exterior PVC-Coated Steel Pipe for Fire Fighting). It is used for buried fire-fighting water pipe and interconnected water piping. Fire-fighting pipe SRPG-VS is a pipe material for connecting water pipe according to revision of Fire Law. VS-M is easy to peel off coating and easy to apply to mechanical coupling.
Cable protection Steel Pipe Insertion Joint Coated Steel Pipe MCCP Coated Steel Pipe AS, ASC, APS	Inner surface is excellent in the cable transmission line with internal coating, and the outer surface is cable protection steel pipe for corrosion prevention according to piping environment. In addition to the thread connection, it is also applicable to the insertion joint with excellent workability.

#### 4. Conclusion

JFE Steel has steel pipe products and manufacturing facilities that can answer the various requirements of customers, and is also actively engaged in various types of technology development, even at present. This Special Issue introduces the recent results of technology development.

#### References

- 1) Morioka, N.; Oka, H.; Simizu, T. Development of Manufacturing Technology for High Alloy Steel Seamless Pipe by Mannesmann Process. Kawasaki Steel Technical Report. 1998, no. 38, p. 38–46.
- 2) Fujibayashi, A.; Omata, K. JFE Steel's Advanced Manufacturing Technologies for High Performance Steel Plates. JFE Technical Report. 2005, no. 5, p. 10–15.
- 3) Toyooka, T.; Itadani, M.; Yorifuji, A. Development of Manufacturing Process "HISTORY" for Producing Innovative High Frequency Welded Steel Tubes with Excellent Properties. Kawasaki Steel Technical Report. 2002, no. 47, p. 1–8.
- 4) Kimura, M.; Tamari, T., et al. High Cr Stainless Steel OCTG with High Strength and Superior Corrosion Resistance. JFE Technical Report. 2006, no. 7, p. 7–13.
- 5) Kimura, M.; Miyata, Y.; Shimamoto, K. Corrosion Performance of Steels in Deep Oil and Gas Wells and New Corrosion Resistant Oil Country Tubular Goods. JFE Technical Report. 2007, no. 17, p. 42–46. (in Japanese)
- 6) Martensitic Stainless Steel OCTG with Premium Connection. JFE Technical Report. 2007, no. 17, p. 59–61. (in Japanese)

- 7) Ishikawa, N.; Endo, S., et al. High Performance UOE Linepipes. JFE Technical Report. 2006, no. 7, p. 20–26.
- 8) Koide, T.; Kondo, H., et al. Development of High Performance ERW Pipe for Linepipe. JFE Technical Report. 2006, no. 7, p. 27–32.
- 9) Nakata, H.; Kami, C.; Matsuo, N. Development of API X80 Grade Electric Resistance Welding Line Pipe with Excellent Low Temperature Toughness. JFE Technical Report. 2008, no. 12, p. 27–31.
- 10) Inoue, T.; Suzuki, M.; Okabe, T.; Matsui, Y. Development of Advanced Electric Resistance Welding (ERW) Linepipe “Mighty SeamTM” with High Quality Weld Seam Suitable for Extra-Low Temperature Services. JFE Technical Report. 2013, no. 18, p. 18–22.
- 11) A Martensitic Stainless Steel Seamless Pipe for Linepipe. JFE Technical Report. 2007, no. 17, p. 62. (in Japanese)
- 12) Miyata, Y.; Kimura, M., et al. Martensitic Stainless Steel Seamless Pipe for Linepipe. JFE Technical Report. 2006, no. 7, p. 14–19.
- 13) Toyoda, S.; Suzuki, K., et al. High Strength Steel Tubes for Automotive Suspension Parts -High Strength Steel Tubes with Excellent Formability and Forming Technology for Light Weight Automobiles. JFE Technical Report. 2004, no. 4, p. 32–37.